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# FIVE HUNDRED THOUSAND BITS FROM VENUS

R. Svoren'

Translation of "Pyat'sot tysyach bit s Venery," Nauka i Zhizn', No. 4, April 1976, pp. 38-43

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16. Abstract

The author reviews communications aspects of the Soviet Venera-9 and Venera-10 missions. Some historical developments leading up to these missions are presented, and so are some of the constraints imposed on communications during various mission phases.

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FIVE HUNDRED THOUSAND BITS FROM VENUS

Moscow NAUKA I ZHIZN' in Russian No 4, April 1976 pp 38-43

[Article by R. Svoren', special correspondent]

[Text] When we call these experiments fantastic or incomprehensible, it is more likely a statement of fact and not hyperbole. Please recall: A relatively large device, the size of an automobile, rapidly receding from earth, flies in the lifeless ocean of space for 4 months, and then precisely hits Venus, which is floating in her own orbit. And from there, using a communication link 70 million km long, rushes to earth radiograms and images coded in electrical signals which are being seen on that planet itself by a fearless electronic eye.

It is difficult to visualize all of this; there is not enough imagination. For thousands of years, Nature whittled and polished her best creation, man, and adapted him to solve her diverse problems. A grain of sand on the palm, a rock the size of a fist, a forest at the horizon, a two-day march to the nearest river--these are the scales that we have inherited from our ancestors, and we are used to thinking in those terms. Frequently we have just barely expressed our admiration for a current discovery or achievement when we find ourselves used to brand new phrases such as "billion light years... it is encoded in the structure of protein...nanosecond...soft landing on Venus...a billionth part of a mm...a line of communication 70 million km long ...quantum transition...." There is not always enough opportunity to think these through, to reflect, to take interest in the details. And yet it can be that some details would serve better than anything else to visualize a new, complex fragment in the image of the world.

The automated station Venera-9 is a relatively large piece of equipment (mass, 4,936 kg) and is rapidly increasing its distance from earth (initial speed was 11 km/s, and, moving with such a speed, one could go from Moscow to Leningrad in 1 min and to Tashkent in 3 min). Before that, there was the cosmodrome, the huge rocket, unending checks and tests, a festive mood and the tension of the launch, several minutes of powered flight culminating in the injection of the station into a near-earth orbit. And then, from this orbit, after one more set of checks and thorough aiming as well as the precisely timed final firing of the last stage, the decisive shot. Not toward Venus, but in the exactly opposite direction.

A word of explanation is the book "Venus Reveals Her Secrets" by V. Alekseyev and S. Minchin, recently published by Mashinostroyeniye, one section of which we briefly and freely recall.

Many different routes exist by which a spacecraft can get from earth to Venus. The most natural thing, it would seem, would be simply to fall down onto the planet (Figure 1, colored insert, and to which insert all remaining figure references are made).* To do this, the velocity $v_3$, which this spacecraft has when it is moving with the earth (the orbital velocity of the earth is 29.76 km/s, about equal to 110,000 km/hr), has to be neutralized, and, at the same time, a velocity $v_c$ in the direction of the sun has to be imparted to the spacecraft in order that the spacecraft overcome the attraction of the earth. While falling to the sun, the spacecraft will intercept Venus at the place that her orbit crosses the straight line trajectory, the shortest one for the spacecraft. For this case, the time of flight can be just 25 days, and the route just 42 million km long. But for the shortest route there are shortcomings and at least one of them is hard not to reckon with, namely, that the spacecraft has to achieve an initial velocity of 31.8 km/s; but such velocities are beyond the capability of current rocket technology.

Among all the terms used by specialists in discussing different versions of space experiments, the most important one is weight. Payload weight is paid for by the launch weight of the rocket, and the price per kg also depends on the choice of space trajectory. In launching toward Venus, the weight placed into near-earth orbit is apportioned between the interplanetary craft and the final stage of the rocket that is used to give the final acceleration to the spacecraft from earth orbit. The most advantageous situation exists when this final acceleration can be made with minimum expenditure of fuel and thus with a maximum useful load. Such a situation is brought about as follows: In accelerating the spacecraft, it is aimed so that it will coast along a complex curve and approach the orbit of Venus (Figure 2) while during this coasting time the planet itself approaches the place of interception. The basic parameters for this flight are: Length of path is 600 million km, time of flight is 6 mo. In practice, this economical case is never used, since, for a prolonged flight and because of difficulties in aiming accurately at the target, there arises a large probability of difficulties en route. Also, when the spacecraft is landing on Venus, it would be 90 million km from earth, and it becomes more difficult to establish a dependable line of communication with increased distance.

A scrupulous weighing of all pros and cons leads to several compromise versions for this flight, which turn out to be closer to the latter, or most advantageous, than to the first, or shortest trajectory. The basic parameters of the intermediate routes are: Time of flight, about 4 mo; path length, about 360 million km; distance from earth to Venus at the moment of landing, about 70 million km. It is along these routes for the flight to Venus that all Soviet interplanetary stations, among them the last two, Venera-9 and Venera-10, were launched.

* Not reproduced in this translation.

The long months of flight are far from being a time of hibernation for the automatic station. The station is alive, many of its systems working. In particular, based on signals from temperature transducers, onboard ventilating fans are turned on and off, and air valves of the temperature-regulating system are opened and closed, thus maintaining a positive temperature of about 20°C. One of the continuously turned-on duty receivers is always ready to receive signals from earth, decode them, and transmit them to the station command point in the control system. Indications from numerous scientific instruments, data from astronavigation systems, and information about what is going on in the station itself are written into the memory system. At the time of a regular communication period, all this information can be transmitted to earth. At any given moment, in accordance with its own program or in response to commands from earth, the attitude control system can start operating in one of its modes. By observing the light from the heavenly beacons through the astronavigation instruments, the station determines its position in the starry world and its attitude in space. With a jeweler's precision, an orbit correction is executed, and the station unerringly follows the invisible trail leading to Venus.

Just yesterday, such terms as astronavigation, space orientation, and orbit correction were mysteriously intoned only by the most educated heroes of science fiction. Today they are in student dictionaries: One absolutely has to understand all of this in order to get a feel for the tremendous effort that lies behind such a now-common term as "space flight." Figures 7 to 12 illustrate several typical modes of interplanetary station travel along the flight path. The mode shown in Figure 7 represents the constant solar-aspect orientation, in which the solar panels are directed toward the sun, and the station is supplied with the sun's free energy and charges its batteries, thereby replenishing its supply. The constant solar-aspect orientation mode is monitored by a solar sensor, which can be thought of as a system of photo elements with an optical objective (Figures 5, 6), a kind of many-eyed photo light meter. During correct orientation of the solar batteries, this sensor is aimed precisely at the sun and all its photo elements view the solar disk equally and therefore generate equal currents. But should the station turn even slightly away from the sun, the balance of the currents will be upset. At this instant, a correction signal is produced in the electronic control system, into which all currents from the photo elements are directed. The control system will in turn switch on the cold reaction micro-rockets (they use the same principle as a small balloon with compressed gas), which will turn the station back into place.

Depending on the distance that the station recedes from the earth, the constant solar-aspect orientation mode (orientation in only one plane and about one axis) ceases to meet the requirements of the radio engineers to have the station transmitters maintain communication with earth using narrow-beam antennas. These antennas do not disperse the radio waves in all directions but radiate only in a narrow bundle, which is reminiscent of a searchlight beam and which gets wider the farther it gets. This is brought on by the goal of effectively using the power of the onboard transmitter at great distances from the earth, which in turn makes it possible to reduce the weight of the transmitter itself and its power supply.

To aim the radio beam of the narrow-beam antenna at the .¢th, upon command from earth, the station (Figure 8) goes from the constant solar-aspect orientation mode into a constant solar-stellar orientation mode (Figure 9). The solar panels are aimed at the sun, as before, but the station assumes a precisely defined attitude in the plane of these panels, rather than a random one. This is controlled by a second optical sensor, a stellar sensor, which stays locked on to its own predetermined star similar to the way that the solar sensor does with the disk of the sun. In the constant solar-stellar orientation mode, there is one sensitive area, namely, that the station and the earth constantly move with respect to the sun and thus change the angle among directions to the earth, sun, and star. Therefore, it is necessary to calculate and adjust the aim of the sensors during flight, so that the narrow-beam antenna will not deviate from the commands under any circumstances and will point precisely at earth.

Then comes the moment when the constant solar-stellar orientation mode is interrupted and one of the most important and complex operations, the trajectory correction, is performed. The position of the spacecraft has been precisely measured, its speed precisely computed, and the direction and amount of acceleration determined so that it will stay on the path. This is accomplished by complex automation systems in which the invisible threads of radio beams connect into one whole the onboard equipment with that on earth. The station is turned to the computed attitude, at the predetermined moment the powerful rocket motor is switched on, and the desired amount of acceleration is delivered (Figure 11) by monitoring the increasing velocity. And when the correction is finished, a special system that remembered the attitude of the station before this maneuver returns it to the constant solar-stellar orientation mode (Figure 12).

We should probably add to these extremely simplified descriptions that there are many thousands of precisely interacting devices, elements, and assemblies in the systems for orientation and in those used for navigation and for attitude correction. What appears to be simple at first glance, such as adjusting a poorly aimed antenna to a sharply aligned position, the return of the station to the constant solar-stellar orientation mode, or communication with earth, are long chains of events such as "switched on," "switched off," "received," "executed," "checked," each of which has to be executed precisely and reliably at the right moment. And yet, during the time of flight of the Venera-9 and Venera-10 probes, more than 100 communication link-ups were made, each station executed two corrections, and arrived at the desired place in the vicinity of Venus at the predetermined time. Dr of Technical Sciences V. Ye. Ishevskiy, in response to questions from the magazine NAUKA I ZHIZN', tells us what happened next.

[Question] Would you, Valentin Yevgrafovich, please tell us, if possible, of what this exciting event, the arrival of the station on Venus, consists?

[Answer] Here, I dare say, we are faced with a whole chain of exciting events, stretching in time over several days. As the beginning, we can probably count the planet-approach correction with all its complex and decisive ingredients, such as the precise determination of the impulse required, orientation of the spacecraft, its stabilization, switching on the power plant, checks on the change in the velocity vector, and return of the station to the constant solar-stellar orientation mode. Then follows the separation of the spacecraft into two independent parts, the descent module and the orbital module (Figure 13). The descent module is separated from the orbital module and the two modules fly alongside each other for some time along a so-called impact trajectory headed to the planet's surface. The descent module remains in this trajectory, but the orbital module fires the main propulsion unit at a predetermined moment and executes an exit maneuver, which puts it into a flyby trajectory, that is, a trajectory that goes past the planet. Then, 1,500 km from the planet, one more firing of the propulsion unit takes place, of course after turning and a precise orientation in space, and the orbital module, justifying its name, enters an extended elliptical orbit and becomes an artificial satellite of Venus.

During this time, the descent module, continuing its fall to the planet, enters into the upper layers of the atmosphere and begins the complex descent and landing sequence. The speed with which the descent module enters the planet's atmosphere is about 11 km/s, which in more familiar terms is almost 40,000 km/hr. Due to this high velocity while still beyond the high-density atmosphere, tremendous mechanical and thermal loads are put on the descent module.

[Question] What numbers lie behind the word "tremendous?"

[Answer] The plasma surrounding the spacecraft has a temperature of 10,000° when it is moving in the upper layers of the atsmophere...the mechanical load on the front portion of the descent module is about 300 tons...this equals six large, loaded railroad cars...one more number--due to natural braking in the atmosphere, the velocity of the descent module quite rapidly decreases 50-fold ...and when it reaches about 900 km/hr, the onboard automation system begins the second braking stage by using a parachute system.

[Question] All these apparently tremendous loads pose quite complex problems for the designer.

[Answer] Of course...but these are not all the complex problems by far...the initial stresses are short and last only for seconds. But it is also required that the module operate for a sufficient length of time on the surface where the atmosphere has a pressure of about 90 at, roughly equivalent to the ocean depth at 1 km. Such a pressure will crush the roof of a light automobile even if it is made from sheet steel several cm thick. And the temperature on the surface is around 500°C, at which aluminum becomes as soft as wax and, of course, lead and tin melt.

For the complex onboard equipment, this is an intolerable heat. (Look in any radio engineering handbook--even silicon semiconductor devices, which are the champions of thermal tolerance, cannot stand any more than 150°C, and even their parameters deteriorate badly in the high-temperature region.) Therefore, the battle to keep the equipment on board the descent module from heating starts long before landing, in order to postpone as long as possible its thermal death.

The descent module is super-cooled while it is still flying through space, and negative temperatures are created in the equipment section. On the planet's surface itself, the ventilators inside the descent module start to operate and, together with special heat sinks, make it possible to keep essential assemblies inside the equipment from heating up until the very end. External and internal thermal insulation, of course, is also important. However, all this is but one side of the coin, only one set of problems. It is also necessary to slow the descent module down accurately, to land it softly, and to provide stability even when the descent module lands on the side of a mountain...this list can be continued, but I think it is more important to point out something else: The design problems are only a part of the myriad of problems solved by specialists in propulsion, astronavigation, orientation, orbit correction, flight dynamics, radio communication, ballistics, onboard automation, and in the scientific researches for whose benefit, in truth, the whole experiment is being conducted.

With each spacecraft success, we remember chief designer Georgiy Nikolayevich Babakin, member-correspondent of the academy of sciences, hero of socialist labor, and Lenin award laureate. He headed the design bureau where many spacecraft were created including those that explored Venus.

The exploration of Venus has come a long way: The first impact on the planet (Venera-3, 1966), the first parachute descent and direct measurements in the atmosphere (Venera-4, 1967), descent and measurements down to 30 km above the surface (Venera-5, Venera-6, 1969), first transmission of scientific information from the planet's surface (Venera-7, 1970), transmission from the daylight, or sun, side of the planet (Venera-8, 1972), and finally, the creation, based on knowledge gained from the preceding experiences, of the Venera-9 and Venera-10 stations, which differ in many ways from their predecessors. In particular, in the area of technology for descending into the planet's atmosphere....

[Question] In describing the arrival of Venera-9 on Venus, you have come to the moment where the parachute system is about to be used....

[Answer] There are several parachutes for the station. The first to appear is a small auxiliary parachute that deploys after jettisoning* of the upper cover of the thermal protection jacket; this parachute takes the cover from the module (Figure 14). Then the lower cover of this jacket is jettisoned....

[Question] Many of our readers will no doubt want to know what is meant by "jettisoning...."

[Answer] Here we have the fortunate circumstance where the term does not require translation but accurately reflects the essence of the matter. In order to separate and to push away one part of the spacecraft from another, a pyro charge is used, as a rule, that consists, say, of a small cylinder with some type of gunpowder charge with a piston and pushrod. On appropriate

* Literally: "shooting away"

command, an electrical impulse ignites the charge, a pressure on the order of 1,000 at pushes on the piston, and it does the required work. This method is used, for example, to separate the descent module from the orbital module and to jettison the lid of the thermal protection. And to the point, at an altitude of about 50 km, the main parachute is jettisoned and the speed of the module's descent begins to increase....

[Question] And why is this done?

[Answer] From among the parachutes of the descent module, the first one to be deployed is the braking parachute, which reduces the descent velocity to 50 m/s, that is, to 180 km/hr. The onboard transmitter begins to operate and scientific information flows from the descent trajectory to the orbiting module and from there directly to earth. After some time, the basic three-canopy parachute, with an overall area of 180 $m^2$, is deployed, and the descent module slowly passes through one of the most interesting segments of the flight, the layer of clouds. Following this, scientists have no interest in a slow descent, and any extra flight time through the hot atmosphere will increase the temperature of the descent module and thus shorten the time available for its operation on the planet's surface. It is for this reason that the main parachute is jettisoned and the descent module begins to fall much faster, being braked only by a very stiff umbrella using aerodynamic braking. The entire descent phase of the descent module has one other important peculiarity: It has to be synchronized with the flight of the orbital module. When the descent module has landed, the orbital retranslator (on the orbital module) has to be at the point of its orbit from which it is possible to establish reliable radio communication from the descent module to the earth. As is known, it is by this interaction of descent module and orbital module that the flights of Venera-9 and Venera-10 were carried out, and a tremendous amount of information was transmitted.

The concept "information," even though it rules the world of cybernetics, has yet to be put into school textbooks, and the unit of the quanity of information, the bit, has yet to take its deserved place alongside such terms as watts, liters, meters, and amperes. None other than communications people were the first to learn to measure information, and the word itself in its current form came from the theory of communication. The difficult question of the usefulness and value of communication remained on the sidelines, and the impassive measure of information became the quantity of the simple electrical signal-impulses necessary to transmit words, texts, and images, regardless of their contents. The smallest measure, one bit, is a single impulse or pause, a single "yes" or "no." With 32 letters in the alphabet, in order to transmit each one of them, certain combinations of five impulses or pauses, five yesses or noes, are required. Thus, the amount of information in a single letter is five bits. The word "nap" has three letters, and thus 15 bits, while the word "thermo-conduction" has 16 letters and thus contains 80 bits of information. A chessboard has 64 bits, namely 64 either black ("yes") or white ("no") squares. A page of typed text contains approximately 10,000 bits, a photograph in a newspaper has about 200,000 to 300,000 bits, and a 5-min conversation has several million bits.

Having been spoiled by the ease of obtaining information by kilobits and megabits that we receive from the television screen, radio receivers, or a telephone line, we are seldom interested in the price that has to be paid for all this by the communications system. And the price is high, measured in two forms of currency, seconds and hertz, which express the time of transmission and the frequency bandwidth, which has to be passed through a communication channel. (The frequency bandwidth of a television signal is 6 MHz, and it is necessary to pass all frequencies in the interval along a line of communication for television transmission, for example, from 50 to 56 MHz or from 2,000 to 2,006 MHz; the frequency bandwidth for telephone conversation is typically 3 kHz; more detail on this is given in NAUKA I ZHIZN', No 9, 1975, pp 32-34.) But the currency of hertz and seconds can be taken in any proportion, since the only important thing is the total: The smaller the time allowed for the transmission of information, the wider the spectrum transmitted has to be, and vice versa, the narrower the band being transmitted, the longer is the time required for transmission. A telegram of 1,000 bits can be transmitted in 1 s for which the communication line has to be able to transmit a frequency band of 4,000 Hz. The band could be cut down to 2 to 3 Hz, but the transmission of the telegram would then take place very slowly, about half an hour. After this preface, we can return to the surface of Venus on which the descent module has just landed and quite knowledgeably make the following comments:

The lifetime of the descent module on the surface is limited; therefore, in order to transmit a large volume of information from it, the information needs to be transmitted very quickly; and thus it is necessary that the line of communication between Venus and earth be capable of transmitting a broad band of frequencies.

It is of course necessary, necessary, if it but could be....

The major obstacle to broadening the frequency band is the tremendous distance covered by the line of radio communication through space, these unending millions of km. The power transmitted from the transmitter to the receiver decreases with the square of the distance between them. And with the square--as the distance doubles the power of the signal that arrives at the receiver decreases by a factor of four, and when the distance increases by 1,000, the power drops by a factor of 1 million. The signal arriving from a transmitter on Venus will be 40,000 times weaker than it would be from an identical transmitter on the moon.

The power of the transmitter on the spacecraft is limited (it is our old friend, the weight!), and, in practice, the power of the signal received on earth from the region of Venus is measured in terms of the trillionth part of a billionth part of a watt. To receive such a signal is, for example, about the same as being in Moscow and want to hear the sound of a bug on his evening walk somewhere in the region of Murmansk. It would seem that there is nothing very difficult in this, since electronics long ago learned to amplify weak signals. Even in an ordinary transistor receiver, the signal is amplified by a factor of 1 million in going from antenna to speaker. Who would interfere with amplifying any signal, no matter how weak, that arrives on earth from an interplanetary station?

It is disturbed by errors or noise, as it is called by radio experts. These are the radio wave signals that generate the chaotic movement of electrons in the antenna of the receiver itself and are caused by solar radiation and radiation from galaxies and distant stars. The level of all these noises is low, and we do not encounter them while listening to earth-based radio stations or television centers. But the extremely weak signals from a distant space station can get drowned in the noises, can get lost in them as a whisper on a noisy street. In this case, amplification is useless since, together with the signals, the noise is also amplified.

Extracting weak signals from noise is one of the central problems in today's radio technology. Among the methods that simplify its solution, the most radical is surgery, a narrowing of the frequency spectrum of the signal. The narrower the frequency gate of the communication channel, the less is the power of the noise that enters through it, and it is easier to extract the signal from it.

And thus we have a conflict: On one side, in order to extract a weak signal from the noise, it should be narrow-band, but on the other side , it is difficult to transmit much information when using a narrow-band signal. Yet the resolution of the conflict is unexpected and bold and consists of using an orbital retranslator (Figures 13-16). Now the relatively low-power transmitter $\Pi_2$ on board the descent module provides a sufficiently powerful signal to the receiver $\Pi_p$ on board the orbital module, since it does not have a long distance to cover, on the order of thousands of km. And not millions. And one does not have to worry about noises, and the transmission can be done in a relatively broad band of frequencies. On board the orbital module is a significantly lower power transmitter $\Pi_1$ equipped with a narrow-beam antenna (the descent module is stationary, while the orbital module can be oriented as desired and the antenna can be pointed at earth). Therefore, the signal from the orbital module arrives on earth again as a quite significantly stronger one than if it were to come directly from the descent module. All this, taken together, produces the most important effect, namely, making it possible to increase sharply, by several hundred times, the band of frequencies transmitted by the communication channels. (The following comparison is offered: Direct transmission from Venus is like being able to hear two or three adjacent piano keys, while retranslation makes it possible to hear multi-note chords spanning several octaves.) But if the frequency spectrum of the signal is broadened, that must mean that the volume of information it is possible to transmit from Venus also increases. And that is the very same priceless product whose volume is increasing and for which this difficult expedition to Venus was undertaken.

The entire volume of information possible for transmission from the surface of the planet is divided among several users. The commutator (Figure 16) sequentially connects different scientific instruments to the transmitter of the descent module. But the major portion of this volume, the major period of communication channel operation, was assigned to the main scientific goal, the simple, human "I saw it!" as Dr of Technical Sciences A. S. Selivanov has commented on this crowning accomplishment of the entire experiment.

[Question] We would like it very much, Arnol'd Sergeyevich, to be able to visualize the equipment to which the photography of Venus was entrusted.

[Answer] We should probably say at the outset that there were no photographs in the broadly accepted sense of this word. Indeed, some times spacecraft photograph an object first and then transmit this image to earth using radio communication. In the case under discussion, there was no need for this. The image was received by a photo-electronic instrument built into the descent module where it was transformed into a series of electrical signals that were immediately transmitted via the orbital module to earth. And here the picture was re-created from these signals.

[Question] This, then, was the usual television transmission?

[Answer] No, I would just as soon say it was photo-telegraphy. In the first place, the picture was transmitted slowly, one frame requiring nearly half an hour. Second, the system did not contain the mandatory television attribute --a television camera tube. Its role was taken by a camera with mechanical scanning.

As is known, in a television camera tube, the image is projected onto a light-sensitive screen in the same manner as, for example, it is projected onto film or onto a plate in a camera. The light-sensitive screen is a huge multitude of the tiniest photo elements, each of which exhibits its own electrical charge in response to the light in the image. This charge is larger the brighter the illumination of a given point. The narrow electron beam of the tube sequentially scans all photo elements, "reads" the charge, and the image becomes coded in the changing current of the beam. This is called scanning the image and transforming it into a television signal.

In a camera with mechanical scanning, an electrical description of the image is also created but by a different method. There is only a single light-sensitive element, more precisely, a photomultiplier, in such a camera. The ray arrives at the photomultiplier after going through the objective and a very small opening in the diaphragm. As a result, the photomultiplier sees only a single point of the picture. But with the aid of the moving mirror (it is rapidly oscillated by the motor-driven cam) located on the traversing platform, the camera gradually views the entire object point by point.

[Question] And what led to the decision to abandon electronic television for the mechanical one?

[Answer] I would not put the question in this fashion...the system, after all, is basically electronic: The photomultiplier itself, its power supply, the amplifier, and the signal conditioners, the synchronization of the motor rotation by using the highly stable reference frequency--these are all pure electronics. As for the mechanical scanning, a good argument can be made for it.

[Question] And what are these arguments?

[Answer] The system with mechanical scanning, frequently called scanners nowadays, is primarily a very precise measuring instrument with uniform sensitivity and sharpness over the entire frame. The whole frame is viewed by just one light-sensitive element, the photomultiplier; the diaphragm limits the light to the beam that always passes through the center of the objective. In such a system, a huge panorama is captured by one stroke of the pen and does not need to be pieced together from many. And the automatic control of amplification makes it possible to compensate for nonuniform illumination of the object. At the same time, however, the main merit of electronic scanning, the lack of inertia, is lost due to slow transmission.

At one time it was necessary to prove that scanners are irreplaceable for many space television systems. Today, nobody is disputing it...scanners have proved their merits in that very same business. The Luna-9 station, which celebrated its 10th anniversary this year, was the first to make a soft landing on the moon and to transmit the first lunar panoramas to earth. These panoramas were made using scanners of the same kind that subsequently worked on other Lunas, on the Lunokhod, on Mars, and on the latest Venera spacecraft. To the point, our American colleagues, who have always preferred a purely electronic device, are also installing scanners with mechanical sweeps on their latest spacecraft, the Mars Vikings.

[Question] At one time, a colored photograph of Mars was received from the Mars-5 station. What device made it?

[Answer] Here indeed the planet was photographed to start with, the film was developed on board the spacecraft, and the picture was then read by a scanner. Dozens of frames were taken, several of them through multicolored light filters, and from them the color image was synthesized. Other television systems were also installed on the Mars spacecraft. In particular, a scanner without horizontal sweep was used, which was replaced by the motion of the spacecraft itself above the planet (Figure 15). As a matter of fact, such a system has been installed on each of the latest Venera spacecraft to image the planet's cloud layer. The television signal can be transmitted to earth immediately, or it can be recorded on magnetic tape and transmitted at a different, more convenient time. Or it can be transmitted repeatedly. The magnetic tape recorder can also record the signals from the descent module.

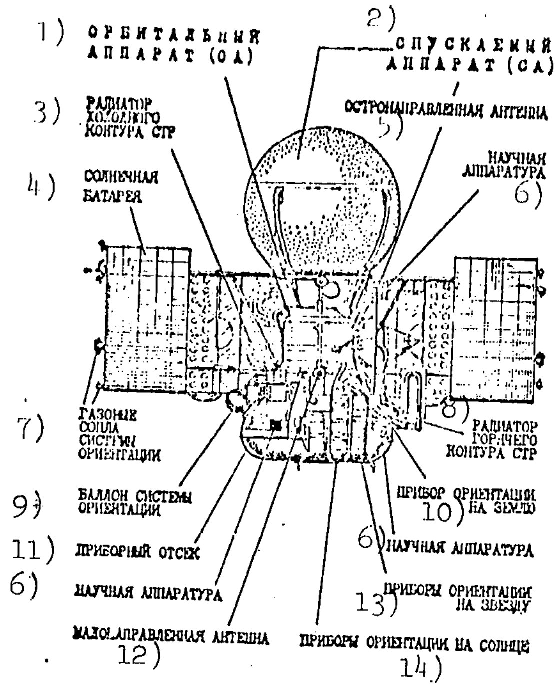
[Question] What is the volume of information transmitted to earth for the reconstitution of each Venusian landscape?

[Answer] Approximately 500,000 bits....

That is quite a few...this is equivalent to a telegram of 5,000 to 10,000 words....

That is the penalty we pay for sharpness. The scanner will have swept the picture with more than 500 lines, each line containing 128 elements, so that the whole picture is made up of about 70,000 points. And not just black and white as in a blueprint, but having different gradations of brightness, such as in television or photography. Provisions were made to transmit 64 brightness gradations. Thus each point required six bits plus one additional, the so-called service bit, for synchronization. In this fashion, one pays dearly for the transmission of an image, since 500,000 bits are not a trifling sum, but there is also much useful information in the pictures. Using the landscapes obtained of Venus, specialists in the area of planetary geology use them to work on the question of the planet's origin. And those who talk of subsequent flights....

To the important scientific results brought to earth by these thousands of bits of television signals, we have to add one other that has no price at all--we saw Venus.




Figure

Key:

1. Orbital module
2. Descent module
3. Cold-loop radiator
4. Solar panel
5. Narrow-beam antenna
6. Scientific equipment
7. Attitude control system gas nozzles
8. Hot-loop radiator
9. Attitude control system gas container
10. Earth-seeking sensor
11. Instrument bay
12. Antenna of low directional capability
13. Star-seeking sensor
14. Sun-seeking sensor